A PROGRAMMATIC REVIEW OF THE NORTH AMERICAN BREEDING BIRD SURVEY

REPORT OF A PEER REVIEW PANEL

FEBRUARY 2000

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EXECUTIVE SUMMARY

A Review Panel met in April, 1999 to review scientific and operational aspects of the North American Breeding Bird Survey, to assess its relevance to goals of the sponsoring agencies, and to make recommendations for improvement.

The Panel noted the exceptional cost-effectiveness with which BBS fulfills a large number of important agency goals of the sponsoring agencies: the USGS Biological Resources Division and the Canadian Wildlife Service. BBS strengths include a stratified random sampling scheme, standard data-collection protocols and extensive geographic and species coverage, all of which contribute to making BBS the primary source of information in North America for population status of landbirds. BBS has been very effective in getting results out to agencies that need this information, and BBS products are heavily used both in scientific and management contexts.

The Panel nonetheless recognized several aspects of the Program that should be addressed if the BBS is to maintain and increase its value for conservation purposes. These include technical issues related to BBS data collection, issues relating to BBS Office operations and management, and suggestions for new directions. These issues are discussed in detail, with justification for the specific recommendations made.

Panel recommendations to improve the scientific underpinnings of the BBS focus on investigation of biases in BBS data. Specific recommendations are to investigate the effects of replacing routes lost to increased traffic flow, to quantify the magnitude of census efficiency, to determine the extent to which BBS routes are representative of the land use and land cover of North America, and to quantify further any bias in counts or trends associated with the roadside nature of the BBS. Operational review includes recommendations to strengthen the ability of the BBS Office to fulfill its mandate, including recommendations for a modest increase in staff, for continuing efforts in maintaining a qualified observer pool and for ensuring a well-documented data set. Further recommendations seek to promote greater scientific use of the data by the production of maximally useful analysis tools and products, particularly through continued Web site development. A general feature of the operational recommendations is an emphasis on standardization and consistency in areas where practice has evolved over time. Finally, future directions are suggested that could further enhance the recognition, value and applicability of BBS. The periodic acquisition of habitat data along the individual routes is recommended, as is continuing effort to integrate the potential of the BBS with ongoing research at Patuxent and elsewhere.

While all recommendations were considered important, the Panel divided them into high, medium and low priority groups, based primarily on the need for more immediate action by BBS management. This list appears in Section 7, which should be read as part of the Executive Summary.

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1. BACKGROUND TO THE BBS

The North American Breeding Bird Survey (BBS) has been in existence since 1966 and provides a continent-wide program to monitor the status of North American bird populations. It is currently operated by the USGS Biological Resources Division (BRD) in partnership with the Canadian Wildlife Service (CWS), which oversees operations in Canada.

The BBS is based on a continental network of volunteer observers who conduct annual surveys of birds along pre-determined routes in the United States and Canada. BBS routes are located randomly within physiographic strata, a stratification intended to reduce variability in counts associated with turnover in habitat and to allow for the varying availability of observers in different parts of the two countries. Each BBS route consists of a 25 mi (40 km) stretch of secondary road, along which birds are counted each year at each of 50 stops 0.5 mile (0.8km) apart. The survey is conducted on a single day during the local breeding season i.e., mostly in June but in May in southern states and in July in the far north or at high elevations. At each stop all birds seen or heard within 0.25 mi (0.4 km) of the stop are recorded (Peterjohn 1994). Data are submitted, increasingly in digital format, to the BBS Office at the Patuxent Wildlife Research Center in Laurel, MD, which works closely with the Canadian Wildlife Service to ensure compatibility in the U.S. and Canadian components of the Program. The data received are checked for quality and are used in analysis of bird population trends in both countries. In 1965 some fifty routes were surveyed as a methodological pilot. In 1966 the scheme started formally with about 600 sites in the United States, Quebec and the Maritime provinces, and by 1968 BBS had expanded to about 2000 routes across the conterminous U.S. and southern Canada. Since that time both geographic and numerical participation has increased, with nearly 3,000 routes now surveyed annually in the two countries.

No formal review of the BBS has been undertaken, but several peer-reviewed studies - some by BBS staff and some by independent researchers - have examined individual facets of the Program. Since the BBS data have been used principally to estimate the spatial distribution and magnitude of population trends (e.g. Robbins et al. 1986, Peterjohn and Sauer 1993, Sauer and Droege 1992, Sauer et al. 1997), most of these reviews have focused on aspects of the program pertaining to trend detection, notably on issues of census bias and efficiency (e.g., Bart and Schoultz 1984), trend analysis (Geissler and Noon 1981), and control of bias and variability (Sauer et al. 1994). A particularly active area of research has been in the development of methods of trend analysis, where a vigorous debate has developed (Sauer and Droege 1990, James et al. 1996, Thomas 1996). However, the spread of new technology and new methods of quantitative analysis have also led to a variety of new applications of BBS data, particularly in biogeography (Maurer 1994, 1999, O'Connor et al. 1996), areas of research not always readily supported by the present design and practices of the BBS program.

The tremendous success of the BBS program, both in participation and in demand for BBS products, has necessitated adoption of modern information management methods. Because BBS has been accepted as the primary source of trend information for landbirds in North America, its results are increasingly considered in funding and management decisions, focusing greater attention than ever on the scientific quality and operations of BBS. A peer review of the entire program at this stage of its development is therefore particularly relevant.

2. CHARGE TO THE REVIEW TEAM

The Director of the Patuxent Wildlife Research Center, Dr. James Kushlan, commissioned an independent Peer Review Panel to conduct an objective assessment of the current Breeding Bird Survey Program and to suggest future directions for its next decade. The Review Panel was specifically requested to consider the following five goals[1]:

Evaluate the scientific quality of the BBS, with respect to a) scientific products[2] b) technical basis[3], and c) current and future program goals[4];

Assess the utility of the BBS for continental bird conservation, through a) evaluation of the current products (excluding peer-reviewed publications)[5] and b) recommendations as to potential of future products of value to particular user constituencies[6];

Assess the quality and effectiveness of Program management and operations, specifically in respect of a) internal program management[7] b) effectiveness of support for and assessment of quality of the BBS volunteer corps[8], and c) effectiveness of partnerships with scientific and management users of Program data, in particular with respect to the US Fish and Wildlife Service and the Canadian Wildlife Service[9];

Assess the relevance of the Program to the goals, priorities and policies of the Biological Resources Division of the US Geological Survey[10]; and

Evaluate future directions for the Program, including validation needs and future management issues[11].

The Review Panel, whose membership is listed on the cover page, met at the Patuxent Wildlife Research Center on 21-22 April 1999. The Panel reviewed the extensive documentation prepared for its deliberations by PWRC staff, heard presentations from several PWRC staff members and (by conference call) from CWS staff. The Panel reached preliminary recommendations in the course of their meeting and subsequently developed the present report

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[1] Since the eventual organization of the Panel's Report followed a different outline from that of these five goals, we provide a series of footnotes to indicate where relevant recommendations or comment by the Panel may be found.

[2] See Section 5.2.3 and Recommendations 21-23

[3] See Recommendations 1,2,4,5, and 7

[4] See Recommendations 9, 11-13, 17,18, and 21

[5] See Recommendation 23

[6] See Recommendations 3,4, 8, 13, 16-18, 20, 21, 24, and 25

[7] See Recommendations 11, 14, 15, 19, 28, and 29

[8] See Recommendations 7, 9, 11, 12, 13, and 17

[9] See Recommendations 26-27

[10] See Sections 3 and 6, and Recommendation 32

[11] See Recommendations 6, 7, 10-13, and 30-32

over multiple rounds of email drafts and conference call. The present Report constitutes the unanimous conclusions of the Panel.

3. RELEVANCE OF THE BBS TO GOALS OF SPONSORING AGENCIES

The primary responsibility of BRD, within which the BBS program is supported, is to assist resource and land managers, particularly in the Department of the Interior, by providing them with sound biological information and guidance in applying that information to their needs. The migratory bird information needs and goals of those partners are nearly as diverse as the number of partners themselves. However, several basic, general goals relating to sound natural resources management and conservation are common to the majority of this partnership base, and these are strongly supported by the BBS program.

Information and data outputs of the BBS follow directly from the BRD mission (to work with others to provide the scientific understanding and technologies needed to support the sound management and conservation of biological resources) and goals (most importantly, assessing and reporting the condition of the Nation's biological resources). The BBS is widely viewed as one of the banner initiatives under BRD's Status and Trends program element (Box 1), and consistently has served as a recognized standard for development of other large scale operational wildlife surveys within the Department of the Interior and other agencies and initiatives around the world. Clear links also exist between implementation of the BBS and dissemination of the resultant data, and the strategic science plan of BRD, particularly with respect to "determining the status and spatial and temporal trends of populations and communities" (Biological Resources Division USGS 1999).

Goals

Status and Trends Program Element

Goal I: To assess and report the condition of the Nation's biological resources.

Goal II: To develop a national framework for monitoring biological resources that integrates information at multiple spatial and temporal scales.

Goal III: To evaluate and develop methods, protocols, and technologies for inventorying and monitoring biological resources.

In Canada, the CWS National Wildlife Research Centre, which bears responsibility for BBS in Canada, has as one of its missions "to conduct national surveys and research on migratory birds." BBS is the single most important Canada-wide survey for landbirds, contributing population status for 73% of the 197 landbird species (excluding waterfowl, seabirds and shorebirds) that regularly breed in the country. Results contribute importantly to another CWS responsibility, taken on under the Biodiversity Convention, to produce reports every 5 years on the status of every species in Canada.

The BBS has served as a model for the role of public-private cooperation in collecting scientific data to address the conservation and management needs of land stewards. The widespread use – both direct and indirect – of BBS data during the past decade is unparalleled in the field of wildlife conservation in North America. For example, BBS-derived products form one of the principal cornerstones of the Partners in Flight (PIF) prioritization process (Carter et

al. in press, Dunn et al. 1999), an approach used to rank more than 500 species of North American birds according to their need for conservation action. Conservation planning activities for wild birds in nearly every area and jurisdiction the United States have been influenced directly or indirectly by the inferences drawn from BBS data through active participation in PIF by 17 Federal agencies, 50 state natural resources agencies, the forest products industry, and hundreds of other public and private governmental and non-governmental groups and individual researchers, and will also be used heavily in regional conservation plans in Canada.

4. SCIENTIFIC QUALITY OF THE BBS

BBS is used almost daily as a scientific tool, and as the basis for decision making on a wide variety of management and conservation issues. It is therefore crucial that the survey be as scientifically sound as possible.

4.1. Strengths

The BBS is characterized by a well-designed sampling of roadside habitat at a continental scale. The stratified random sampling design within physiographic strata has allowed the BBS to maximize its use of volunteer resources in populous parts of the US and Canada while at the same time remaining viable in areas with more sparsely distributed observers. As a result the Program has managed to estimate population trends over very large spatial extent without the problems of differential representation of surveys sites between major habitat classes - a problem experienced even with the Common Bird Census within densely-populated Britain (Fuller et al 1985). The BBS is also characterized by excellent coverage of multiple species. Certain classes of species, including crepuscular and nocturnal species (nightjars, owls, etc.), cryptic species (rails, bitterns, etc.), colonial seabirds (e.g. murres, terns, etc.) and some local species (local endemics), are inadequately covered by the BBS, but for most species that occur at a continental scale the BBS achieves impressive coverage. Moreover, this coverage has been maintained over many years.

Analysis procedures have been developed by PWRC scientists to deal with some of the extraneous variability and bias that is inevitable in monitoring surveys (e.g. Sauer et al. 1994, Link and Sauer 1998). The large number of research papers using BBS data and trends that have been published by scientists outside of PWRC indicate the level of scientific confidence in the importance and quality of BBS.

4.2. Problem areas

Like any population survey, the BBS is subject to bias. While some sources are unidentifiable, others have been identified, and need further investigation.

4.2.1. The road-side sampling frame

For practical reasons the BBS sampling frame includes only habitat near secondary roads whereas the target sampling frame should be all habitat. Implicit in the decision to rely on roadside counts are the assumptions that roads do not bias the measurement of relative abundance by attracting or repelling birds in the area and that off-road trends are the same as on-road trends.

4.2.1.1 Differentials in bird incidence along roads

To test the assumption that birds are not attracted or repelled by roads, it is desirable to conduct a special study using a paired design of counting birds at the usual roadside point as usual but in addition going some (small) distance off the road in the same habitat and counting at another point. Several studies have already used a designed experiment approach to investigate the magnitude of any demonstrable differential in bird distribution along roadsides (Devaul et al. 1990, Keller and Fuller 1995, Keller and Scallan 1999, Bart et al. 1995, Hutto et al. 1995, Rotenberry and Knick 1995). All effects were small in magnitude and confined to relatively few of the species present in each study. However, the locations of these studies were determined by the individual preferences of the investigators, leaving open the possibility of non-representative results. Consequently it is desirable to conduct an investigation that is better designed to evaluate any effect and to quantify the importance of this bias on the reliability of BBS results.

Recommendation 1: The magnitude and direction of the potential on-road bias associated with the roadside nature of the BBS counts should be expressly investigated by testing for attraction or repellent effects of roads with paired counts on and off roads within the same habitat, replicated in different habitats and regions. Alternatively, putative bias could be addressed by building off-road sampling into the BBS protocol.

4.2.1.2 Differentials in on-road and off-road trends

This requires a similar approach to the above, but with the focus on trends rather than simply on magnitude of counts. A roadside bias constant in relative magnitude over time would not introduce a differential between trends estimated from roadside data and that prevailing off-road. Any study of such trend differential therefore needs to be multi-year and, because it must detect a change over time in the magnitude of a bias, will be technically difficult. Careful exploration of the feasibility of such a study prior to substantial commitment of resources to its conduct is therefore desirable.

Recommendation 2: Investigate the feasibility of conducting a designed study to systematically investigate the extent, if any, to which species trends differ on and off roads.

4.2.1.3 Representativeness of roadside habitat

Roads may be located atypically with respect to habitat or land-use, biasing trend assessment. No assessment of the extent to which the habitat and land use around BBS routes is representative of the continental land surface has been undertaken and published. An unpublished study by O'Connor and colleagues within the conterminous United States compared 1990 remotely sensed land cover data in spatial units around the 1200 BBS routes used in their O'Connor et al. (1996) study to the same data for the remaining (approximately 11,400) spatial units of the same size (635 km^2) and found only minor differences. In another unpublished study, P. Blancher (CWS) compared simple habitat data collected along routes by BBS volunteers with remotely sensed habitat elsewhere in the same degree blocks and ecozones. There was a good match in ecozones well-sampled by BBS, but BBS habitat was biased in ecozones with only a few routes (e.g. boreal forest zone). Use of more detailed land cover data, higher spatial resolution data, or of the complete BBS area in the U.S. and Canada would not necessarily yield the same results. It is therefore desirable that a systematic assessment of this

issue be conducted for the BBS as a whole since regional disparities in land cover representation on BBS sites could combine with species preferences to bias trend estimates. Because habitat and land-use patterns are changing so rapidly in North America, the representativeness of BBS routes should be assessed at regular and frequent intervals, preferably every five to ten years.

While examination of potential causative factors for population change is not part of the stated goal of the BBS (Pardieck 1998), environmental data collected at the same locations as bird population data would provide a unique opportunity to examine the relationships between the two sets of parameters and to propose testable hypotheses for future research. This approach of integrating research and monitoring is closely in line with the research philosophy of BRD, and would provide important insight into appropriate future actions for conservation and management of wild birds.

In 1981-82, a pilot effort was undertaken by PWRC to get BBS volunteers to record habitat at each route stop. Further pilot work on this was also undertaken in Colorado in 1996. Also in 1996, the Canadian Wildlife Service BBS office evaluated the possibility of observers classifying route habitats. The classification scheme, done separately from the BBS counts, required estimation of cover types by ground-based observers at 3 different levels of resolution. The time required for estimating cover for 162 routes was minimal (3-6 min per stop). Preliminary analysis of data showed strong agreement among independent observers on the highest level of habitat classification and useful (statistically significant, though weaker) correspondence on second and third levels of detail (Blancher 1997, 1998). Hence, this pilot indicated that volunteer, ground-based habitat classification is feasible and potentially useful. The broad coverage afforded by volunteer classification could, for example, enable separate trend analysis for sites with different types of forest cover or degree of habitat fragmentation.

An alternative approach to documenting habitat is to deploy special habitat survey teams. In 1991 the University of Maine surveyed habitat at each of the 50 stops along some 90 BBS routes in New England, using summer student employees. Very detailed micro-habitat data were gathered for each of the four quadrants at each stop, together with a coarser assessment of the habitat in the surrounding landscape. These results yielded much information on the habitat correlates of the birds present on BBS routes, both when analyzed at stop level and when analyzed at various levels of aggregation (Devaul et al. 1990). An important point to this approach is its cost effectiveness: very high quality data - standardized to a level very unlikely to be achievable with volunteers - were obtained at a very low cost.

A third approach is to geo-reference all stops on all routes (see section 5.2.4.4) and obtain habitat and other environmental information through remote-sensing techniques, such as aerial photography or satellite imaging. This approach undoubtedly would be more expensive than the volunteer-based method, and the resolution of the remotely-sensed habitat information thus obtained may also be limiting. For example, the University of Maine study mentioned above found that about 40% of species were better correlated with very high resolution, microhabitat data than with habitat information at the broader scale. Over the long term, however, remote sensing may provide a more rapid and accurate means of classifying habitat features along routes.

Irrespective of the procedure used to acquire habitat information for use with BBS data, an important issue is the choice of habitat and land cover classification to be adopted. The desirability of coordination with related research suggests that the National Vegetation Classification System, already in widespread use by the Nature Conservancy, Federal land management agencies, and the National Gap Analysis Program, should be the primary candidate, though the need for expressly bird-relevant habitat information may modify this suggestion.

Since continuing land cover changes are likely to be a significant source of impact on bird populations, there is considerable merit in the early establishment of a national land cover database for the current BBS routes. However, any interpretation of analysis of such a database will also turn on the extent to which land cover along BBS routes is nationally representative. For states with active or completed Gap Analysis Projects, conducted under the auspices of USGS/BRD, digital maps of land cover already exist, upon which BBS routes can be projected for purposes of identifying and quantifying land-cover types along BBS routes.

The Panel recommends that a working group be created to evaluate the best means of collecting habitat data along BBS routes for comparison to BBS bird data and for comparing route habitat to that of the wider landscape. Because the most effective means of collecting habitat data to assess representativeness of BBS routes on a regular basis (properly an objective of the BBS Office) may not be the best methodology for studying bird-habitat relations (a more research-oriented question), this working group should make recommendations on the most appropriate role for the BBS Program in collecting habitat data.

Recommendation 3: Establish a working group to develop operational methods of obtaining periodic habitat and other environmental information along BBS routes (ideally every five to ten years).

Recommendation 4: Assess the extent to which the habitats sampled by BBS routes are representative of the geographic areas for which trends are reported, at regular and frequent intervals, preferably every five to ten years.

4.2.1.4 Loss of routes to traffic growth

Over the life of the BBS a number of routes have been abandoned because of loss to encroaching urbanization and development. These routes have typically been replaced by new routes sited along secondary roads elsewhere in the stratum, which introduces a bias. The old routes lose most or all of their birds as the natural and semi-natural habitats around them are destroyed, but the stratum trend estimates do not register these losses because the resulting zeroes have been replaced with positive counts from replacement routes. BBS trends are therefore likely to provide an overly optimistic picture of bird populations in the United States and Canada.

Recommendation 4 should help to identify the extent of this bias, which is presently unknown. However, an assessment of past data might also help: e.g., one might re-compute longer term trends, omitting replacement routes and including old routes (using as species numbers either zeros or numbers obtained through re-surveying the dropped routes).

Recommendation 5: Give greater attention to the potential biases introduced into the BBS dataset by the loss of routes as a consequence of traffic growth. Conduct an analysis of the possible effects of route replacement on trend estimates and

develop a Standard Operating Procedure as to the most appropriate treatment of data involving route replacement.

4.2.2 Detection probability

As with many other large monitoring programs, BBS collects data that indicate relative rather than absolute abundance. A crucial underlying assumption is that population indices are directly proportional to population size (the proportionality constant being a species-specific probability of detection). Furthermore, as comparisons over space and time are critical, it is necessary to assume that the probability of detection does not vary spatially or temporally (Lancia et al 1994). This has been intuitively recognized by the rigid protocols used to keep conditions under which counts are made as constant as possible. However, such rigidity does not control for, for example, variation in the detectability of birds in relation to habitat succession: as a young forest matures and the canopy closes, transmission of song (and therefore observer efficiency) may vary with the forest structure (Hunter and Krebs 1979). There is therefore a continuing need to test these assumptions directly.

There are differing degrees of testing possible here, the details of which are beyond the scope of the present review. Alternatives are as follows:

1. No testing (the current situation).
2. Estimate detection probability both spatially and temporally in special auxiliary studies. This can possibly be accomplished by using multiple observers (Nichols et al 1999), distance sampling (Buckland et al 1993), or a combination of the two.
3. Build estimation of detection probability into the BBS to internally validate the assumption that detection probability is constant. Some or all observers could record distance at which birds were detected, or counts could be conducted using multiple observers.

The Review Panel recognizes the logistical and technical issues involved in solving the detection probability problem. Investigation may show that the problem has a limited effect on BBS results, but the BBS remains vulnerable to criticism on this issue in the absence of action to quantify the bias.

Recommendation 6: Conduct a technical evaluation of the empirical effects of spatial and temporal variation in detection probability. Initial work should examine the feasibility of the alternative approaches to the problem, followed by implementation of the selected option.

4.2.3 Observer quality

Observers vary in quality, between individuals and over time, introducing unknown biases and variability to count data and trends. Even among competent ornithologists differences in ability can arise: among the factors known to influence census efficiency are experience (O'Connor 1981) and age (Ramsey and Scott 1981). Many observers experience significant hearing loss, particularly at high frequencies crucial in detecting the song of certain species - e.g. Golden-crowned Kinglet *Regulus satrapa*, Blackpoll Warbler *Dendroica striata* , Blackburnian Warbler *Dendroica fusca* or Cedar Waxwing *Bombycilla cedorum* - leading to an apparent reduction in the abundance of such species on the route over time. Another effect may be site familiarity, leading an observer to expect a certain species - e.g. a loon on a lake - and consequently to make a special effort to detect it.

It has long been known that these sources of variability in observer censussing contribute distinct "observer effects" to bird survey results, and there are various ways of accounting for a portion of such variation during data analysis. In the British Common Birds Census such effects are handled by observer pairing within years (Bailey 1967), a procedure feasible there with the large sample sizes prevailing locally, but open to "random walks" in trend analysis with more distributed samples (Geissler and Noon 1981). This issue is handled within the BBS by incorporation of an "observer effect" within the trend analysis (Sauer et al. 1997, Dunn et al. in press), but at the expense of assuming that the observer effect is constant over time. This assumption is likely to be valid over the average 4-year span of the typical individual observer contribution to the BBS. However, the distribution of BBS participation duration is skewed, such that there are small numbers of observers surveying routes over a very long time periods. Route survey duration is a weighting factor in trend analysis (Sauer et al. 1997, Dunn et al. in press), so anything that affects the efficiency of such observers over time is especially significant for the scheme. There is also known to be a trend to improvement in the general abilities of the body of observers over time (Sauer et al. 1994), and a factor to account for this is included in PWRC analyses (Sauer et al. 1997). Such improvement obviously cannot continue indefinitely, however, so this factor will eventually need further modification. The Panel therefore believes that the treatment of the "observer effect" in analysis of BBS data needs further attention.

Recommendation 7: The BBS should continue to study the magnitude of observer variability, its effects on BBS results, and methods of addressing observer effects during data analysis.

4.2.4 Methodological uncertainties in trend analysis

Although the Panel was expressly asked not to make determinations as to the technical merits of the different trend analysis programs available, it wishes to note that failure to resolve the issues involved detracts from complete confidence in the BBS trend estimates. Although the different approaches differ by large amounts in only some regions and with some species, the uncertainty needs to be dispelled in a timely manner. The Panel wishes to urge continued efforts to determine the merits and weaknesses of the competing approaches, particularly as they have implications for other recommendations below.

Recommendation 8: Continue effort to determine the strengths and weaknesses of alternative methods of trend analysis and the circumstances under which each is appropriately used.

4.2.5 Incomplete geographic coverage

An important issue for the BBS to address in the near term is the geographic coverage desired for the Program. There are several significant gaps in coverage of the BBS within the United States and Canada, a fact clearly recognized by the BBS program managers (Peterjohn 1994; Pardieck 1998, Downes et al. in press). Additional routes are urgently needed in Alaska, Idaho, Kansas, Montana, Nevada, South Dakota, Utah, and Wyoming, as well as for some of the smaller physiographic regions such as the Adirondacks. In addition, the northern limits of BBS coverage are strongly affected by limits to the road system, and hence, most of Canada outside of the Atlantic seaboard lacks coverage in the northern portions of the provinces and in the Territories. Obvious benefits of increasing the number of survey routes include improved

geographic coverage and more accurate trend estimates for many species, particularly at smaller spacial scales.

Based on analysis of BBS data, the minimum sample size for most trend analysis currently conducted is 14 routes in PWRC studies (Peterjohn and Sauer 1993) but is 15 for CWS analyses (Dunn et al. in press). Although the somewhat arbitrary nature of that recommendation is recognized (Sauer et al. 1997), it is an appropriate long-term goal of the BBS program to raise the sampling effort within all physiographic strata within states to at least 14 routes surveyed annually. (There are approximately 300 state-stratum units, which would require approximately 4,200 active survey routes in the U.S. alone.)

A less pressing, but highly desirable, goal for BBS coverage is to extend coverage in Mexico. A three-year pilot project was begun in Mexico in 1993, but was not completely successful because of lack of an adequate pool of skilled birders. A few routes in Mexico continue to be surveyed through 1999 (by birders from both Mexico and the United States). While the BBS managers believe that permanent expansion of the BBS into northern Mexico is "conceivable" (Peterjohn 1994), three principal issues need to be addressed: intense training and recruitment efforts, the development of a Mexican equivalent of the Patuxent and Canadian BBS Offices, and long-term funding initially to provide small stipends to Mexican participants and help defray travel costs associated with surveying remote areas and eventually to support Mexican administration of their routes.

Recommendation 9: Greater effort should be devoted to achieving appropriate geographic coverage by the BBS, specifically by filling major gaps in coverage within the existing BBS coverage area in the U.S. and Canada and by continuing efforts to extend the BBS into Mexico.

4.2.6. Review of research needs

Recommendations to this point have suggested specific research questions that are a priority for BBS to address in order to maximize the scientific value and credibility of results. From time to time this kind of review should be repeated internally, in conjunction with other USGS/BRD scientists where appropriate, to ensure that priority questions are being addressed and to identify new ones. When questions are not being addressed by PWRC or CWS scientists, BBS management should seek to commission the work from external researchers.

Recommendation 10: PWRC and CWS researchers should periodically and formally review the technical research needs of the BBS program, taking costs and benefits into account, and make recommendations to BBS management as to priorities for ensuring that needed research will be carried out.

5. PROGRAM MANAGEMENT

5.1 Strengths

The Panel finds the general management and operations of the BBS to be in very good shape. The Panel was impressed in particular with the evident dedication and commitment of the staff involved, both on the operations side and on the research side of the BBS. It is clear that the operations staff have managed to operate very effectively at the interface of volunteer input and scientific rigor. The support of a large volunteer workforce motivated only by their enthusiasm, while maintaining the production throughput needed for operational effectiveness, is a demanding role that the staff in the BBS Office have filled remarkably well. The high level of volunteer participation in the BBS is one of the outstanding strengths of the BBS, and requires special sensitivity for not being under the day to day control of management. The Panel wishes also to remark on two other aspects of the Program management. One is the high scientific profile the BBS has achieved, over and above its monitoring function, as a result of the scientific creativity of the research staff who have worked on the BBS data. The second is the extraordinarily low budget in support of BBS activities. A budget at this level would be readily defensible if the sole product were monitoring information for internal agency use, so the wealth of research (both intra- and extra-mural) and management activity stimulated and supported by the BBS data is even more remarkable. The Program has to be characterized as yielding an extraordinarily high rate of return to American and Canadian taxpayers for the level of public funding expended.

5.2 Problem areas

As with all programs that have evolved over 30 years, BBS operation has a few weaknesses, largely the result of incremental changes accumulating in effect over the years. The Panel identified a number of issues where operations could achieve improvements or where action would open new opportunities for building on the strengths of the BBS. These fall under three general areas: maintenance of the observer pool, database management, and disseminating data and product. In addition, the Panel comments on several personnel management issues needing attention.

5.2.1 Maintenance of observer force

The availability of a volunteer work force of adequate size and quality is essential to the continued success of the BBS. It is clear that the BBS operations staff are conscious of this and of the need to promote interest and enthusiasm among volunteers. This seems adequate as far as maximizing the interests of volunteers who have already signed up for participation. However, the Panel has some concerns about outreach efforts to potential future volunteers needed to replace those retiring through age, illness, family commitments, or loss of interest, and to recruits who will be needed to expand the BBS into new areas. For this the main resource available to the BBS is the system of state and provincial Coordinators, which is both a strength and a weakness.

Having regional BBS Coordinators to serve as a single contact point between the national BBS Office and volunteers within a region is a good idea, and should be in place for all states and provinces. While Coordinators have traditionally served as a "filter" for identification of qualified BBS volunteers, their roles are likely to expand if our recommendations are implemented regarding investigation of detection efficiency, collection of habitat data, and increase in geographical coverage.

The weakness of relying on state Coordinators for recruitment is that this is too important an issue to the future of BBS to leave entirely to volunteers without any backing or support from the national Office. The Panel would like to see more active outreach to key members of the BBS volunteer body, in particular to the state Coordinators. The national BBS Office should plan periodic meetings or workshops with State BBS Coordinators. Ideally, such workshops might be held every three years for as many coordinators as can attend. We endorse attendance by BBS staff at the annual meetings of the relevant ornithological societies and the holding of workshops in association with such meetings. The goal of these outreach activities should be to strengthen ties with key organizers, to promote new recruitment of observers, to increase the familiarity of the scientific community (and to a lesser extent the bird-watching public) with the aims and methods of the BBS, and to encourage grassroots support for the BBS and its products (see also section 6). The Panel acknowledges that this outreach effort will involve a significant increase over current budgets for travel by BBS staff but considers this a necessary step to address what otherwise could prove to be a critical weakness in the Program.

Recommendation 11: Promote greater outreach to BBS stakeholders, especially BBS State Coordinators. Major elements in this outreach should include increased personal contact between staff and volunteers, and the conduct by BBS staff of workshops and other activities strengthening a sense of participation by stakeholders in the BBS.

5.2.1.1 Observer recruitment and retention

The system of State Coordinators just discussed is crucial in maintaining a cost-effective network of volunteers. Individual Coordinators have very different approaches to meeting their responsibilities to the BBS, creating openings for complementing their efforts in respect of observer recruitment and retention. The Panel believes that additional opportunities to recruit new observers and to encourage retention of existing observers could be promoted by the BBS Office without undermining the work of the State Coordinators. An improved program of outreach, as above, will increase contacts between volunteers and staff and is likely to yield suggestions as to new ways to stimulate participation and commitment. The Panel believes that the likely continued growth in the scale of the BBS, demographic changes involving retirement of baby boomers from BBS, and the increased BBS activities likely to be needed in future, will necessitate a broadening of recruitment and retention efforts beyond the traditional ones. The form of these efforts will need to evolve over time, and may involve development or promotion of self-training and self-testing materials (see also 5.2.1.2).

Recommendation 12: Begin discussions with State Coordinators and BBS participants to identify ways to increase and strengthen observer participation in the BBS in preparation for its anticipated growth in scale and intensity.

5.2.1.2 Observer quality and standards

Issues of observer variability and bias have been considered as a scientific issue (see Section 4.2.3), but there has been relatively little effort to reduce variation and bias through training or volunteer standards. While CWS has produced training tapes containing songs of common species for each geographic region, and provides these to volunteers requesting them, much more could be done to develop training materials.

Numerous bird censuses have been conducted using prior training of the observers to attain consistent standards of census efficiency (Verner 1985), which generally report that observers reach objectively consistent standards of performance after training. This suggests that the development of a program to train observers to consistent standards would be beneficial, particularly if it focused on reducing variation in detection probability between observers. The traditional training program of instructors accompanying observers into the field and conducting controlled comparisons among observers would clearly pose logistical nightmares for the BBS. Nevertheless, there is certainly potential for improved training. Elements of such a program include circulation of information to observers about potential sources for error (including age-related decline in standards), limited field visits to observers by qualified instructors with the goal of obtaining empirical information to feed back to observers about the frequency of empirical error, provision of training or testing tapes with recordings of bird songs under different field conditions and different auditory levels, and greater use of the BBS Web pages as a source of training and self-testing material. Implementation of such activities will need to be sensitive to the justifiable pride of many volunteers in their already high standards of field skills. Current volunteers are likely to be a good source of ideas on desirable self-training and self-testing materials (e.g. recordings of full dawn chorus for practice in sorting out individuals).

Recommendation 13: Develop programs to train observers to consistent high standards, particularly to reduce variation in detection probability between observers.

5.2.2 Database management

PWRC has made major investments in modernizing the data handling needed by the BBS, and has evidently put sound technical facilities for database management in place. However, the Review Panel found some serious problems with data management and an associated lack of supervisory guidance. The Panel identified three issues - database integrity and correction of past errors in the database, treatment of non-standard routes, and processing of historical stop data - that require attention. Specific guidelines, largely in the form of Standard Operating Procedures, need to be put in place to ensure operational compliance.

5.2.2.1 Database integrity issues

The BBS database has been modified over time, without good documentation. Even though changes were made with the intention of improving the database, the result is that replication of analyses is impeded, data are lost that may be useful for other purposes or in retrospect, and user confidence in the reliability and integrity of the database is compromised. While it is acceptable to flag data in ways that exclude records from standard analyses, these decisions should be easily reversible, and there should be clear documentation of the rationale for various data flags and of the date each edit was implemented. Once annual data have been

released, each update (e.g. after addition of late data) should be given a new version number, and changes since the previous release should be identifiable by the user.

The Review Panel considers the proliferation of undocumented editing to be a serious breach of database integrity and one that PWRC management must address and remedy. It should be possible to reverse many of the changes and edits made to the database in recent years by current staff who remember what was done. This should be accompanied by development of a Standard Operating Procedure for flagging data and for routine documentation of changes to the database in the future. (Addressing historical errors in the data base is a different issue, addressed in Recommendation 16).

Recommendation 14: Develop a Standard Operating Procedure to enforce consistency in editing and to ensure that all edits to the database are reversible and clearly documented. These standards should be applied retrospectively, documenting where they cannot be met.

5.2.2.2 Non-standard routes

Various types of non-standard BBS routes are run (e.g., by canoe or on foot, locations non-randomly selected). Some of these are submitted to the BBS database (but not included in routine analyses) and others are not. Proposals have been made to create additional types of non-standard routes, such as shortened routes for use in roadless areas ("mini-routes" tested in Alaska), and off-road and duplicate counts to compare with standard routes. Certain types of non-standard counts may be valuable to the BBS, whether for research purposes only or for routine incorporation into trend analysis, in which case there should be clear guidelines for how they are to be conducted and under what circumstances. Other types may be of no value to BBS (no matter how great the value to individual researchers) , and accepting data from them may unnecessarily strain BBS resources and mislead managers as to the value of these data.

The Review Panel recommends that order be brought to the current ill-defined status of non-standard routes by defining a formal policy about such routes that reflects their value or otherwise to the BBS Program as a whole. This policy should subsequently guide treatment of data from these routes.

Recommendation 15: Assess the utility or otherwise of non-standard routes and define appropriate Standard Operating Procedures for the treatment of recommended types.

5.2.2.3 Historical stop data

In the past, data were received on hand-written forms, with five pages listing data for stops 1-10, 11-20, etc. Page and route totals were transferred to computer files and were therefore available in digital format. The individual stop counts were available only as original data sheets, and researchers wishing to use the stop data had to request the loan of, or photocopies of, the original sheets and arrange for computer data entry of those records themselves.

Recent advances in the treatment of data involving imperfect census efficiency e.g., Boulinier et al. (1998) - have increased the potential value of stop-level data. Since data are currently entered on a stop basis, the passage of time alone will yield a substantial database of

stop-level data that can be used in analyses of species richness and related metrics. The relatively complete record of historical page and route totals accessible on-line supports many of the immediately conceivable spatio-temporal analyses (e.g. Maurer 1999), and the current data processing therefore seems adequate to immediate client needs.

The utility of reconstructing historical stop-level versus route-level data is a gray area in terms of management guidelines for the Program. While certain lines of research might be facilitated if historical stop-level data were available, the potential client base is likely to be low, limited primarily to a few academic researchers. The high resolution of stop-level data is poorly matched to the national/regional nature of the BBS, and the costs of processing historical data – and particularly of trying to correct past data entry errors - are unlikely to be cost-effective. The Panel would not be against a sample of the historical data being reviewed and assessed as to the extent of errors and as to the cost of the effort needed to correct them, but would want such an assessment conducted with guidance from a statistician. On current evidence we think the correction of the full database will prove unlikely to improve quality of the historical record to any significant extent.

Recommendation 16: Discontinue the practice of processing the historical files to yield stop-level digital data but allow access to the clerical records (with appropriate precaution against loss of the originals) upon request, with the expectation that the individual researchers involved will meet the costs of processing such data for specific research projects. The possibility of PWRC receiving an archival copy of any new or revised digital data should be discussed with the Principal Investigator and the funding agency at the time of the request for access to the original.

5.2.3 Data and product dissemination

The BBS Office essentially has three recurrent annual production tasks - the processing of each year's dataset, its analysis to yield the latest figures as to status and trends, and the dissemination of these results to potential clients. In addition, the Office needs to consider whether the continuing accumulation of data has yielded any new information not adequately addressed by the annual production of trend information. The periodic production of overviews of status and trends is particularly pertinent here. The BBS Program disseminates the annual information primarily via Web pages, supported by information in newsletters to the volunteers and by occasional papers in the scientific literature. The Review Panel endorses the value of these products but identified a number of issues in this area of BBS activities as deserving comment.

5.2.3.1 Timeliness in annual products

Lengthy delay in release of annual data is proving a frustration to users who rely on up-to-date results for a wide variety of purposes, and can discourage volunteers. The current state of computer technology should be making it increasingly easy to release data in a timely manner. A realistic standard date should be set for release of annual data (which should be well under one year and preferably no more than 6 months after the end of the breeding season). Every effort should be made to meet the deadline.

Recommendation 17: Make timely release of each year's BBS data a high priority.

5.2.3.2 Information on product reliability

The routine availability of BBS status and trend information on one or other of the two BBS Web sites means that many consumers of the information will have their sole contact with the BBS Program through those sites. Given this, it is particularly important that critical caveats about the data posted, their quality, and their reliability, should be available in a transparent manner. The "Research" Web sites commendably implement this principle by indicating the minimum number of routes recommended for calculation of a BBS trend, and by providing warnings to the user when a custom analysis is based on very low abundance or when variance is high. Trends are not calculated at all for species that are very poorly sampled by BBS. These features reduce misuse and are valuable features of the web site. Nonetheless there are cases in which a trend is produced without warning, yet is of limited value (e.g. sample size is high in Canada but only a small portion of Canadian breeding range is sampled, or sample size in a particular region is sufficient to justify analysis for only a portion of the full time series). While it is the responsibility of the user to assess the quality of results based on cues of variance, significance and sample size, appropriate interpretation of BBS results would be enhanced if known sampling limitations were summarized for easy public reference. Publicizing results of some form of power analysis to reflect where high variance warrants larger sample sizes than the standard 14 routes for BBS for each species at different spatial and temporal scales would also aid appropriate interpretation of BBS results.

Recommendation 18: Publish, either via the Web or in the literature, an assessment for every species represented in the BBS database, indicating geographic, temporal, and other major limitations in sampling that affect quality or generality of trend estimates. All PWRC web sites presenting BBS results should indicate which species have had such limitations identified (preferably linking to the specific details).

5.2.3.3 World Wide Web pages

The Panel considered PWRC's use of Web pages to communicate BBS information, data, and results to a wider community to be extremely successful, and commends the efforts by those involved. The evident increasing reliance by the scientific and management communities on these Web pages as a resource suggests to the Panel that the following issues now need increased attention: control of data and analysis program versions, user-friendliness, and cross-referencing of web sites.

A growing problem with increased use of Web sources is the stability of the site and its material. While the BBS research page does have a version number (Sauer 1997), the Panel was uncertain whether the database and/or program details may have been updated over the period that version number has been in use. The use of Web sources for BBS analysis is moot if versions change without documentation or if repetition of earlier or historical analyses are made difficult by extensive changes. The Panel acknowledges that it may be impractical to allow routine retrieval of earlier analysis programs or data sets as the Web site changes. However, the Panel does consider that as the minimum each database update and each change to the standard analysis program should be signaled with a version number and a simple explanation of changes since the previous version. The version numbers for program and datasets should be cited whenever results are presented (whether on the Web or in print) so that users know the basis of the analysis in enough detail to allow repetition later. While research should continue as to

"state-of the art" trend analysis, a standard method should be chosen for routine use and only replaced after a better alternative has been identified and documentation is complete.

Recommendation 19: Develop a Standard Operating Procedure to ensure documentation of changes to BBS Web sites, at the minimum issuing a new version number for a modified program or dataset and documenting the changes. Such version numbers should be cited in all publicly available analyses.

The ability to replicate previous analyses is an important element in scientific practice, to allow checking for errors in analysis specifications and for changes in the data set. The bootstrap analyses used in a number of BBS Web-based analyses are a valuable tool but as a result of the built-in randomization yield different results with different runs of the same dataset. By contrast, the CWS analysis program uses a jackknife procedure for estimating variance, a procedure for sampling without replacement which always produces the same result. While there are good reasons to allow bootstrap analyses as a user option, it is highly desirable that subsequent repetition of an analysis should be able to yield *exactly* the same results as were obtained earlier. In many computer programs this is achieved by allowing the user to "seed" the random number generator to a specific value. For most users this option will be of little practical use but its provision within the Web tools supported by PWRC would be in line with best scientific practice.

Recommendation 20: On all BBS Web pages that present bootstrap analyses, provide an option for seeding the random number generation to ensure exact replication of bootstrap sequences.

The Panel commends the PWRC staff for their efforts to allow users to undertake on-line analysis of data subsets of interest to them. This is a valuable feature of the Web site that the Panel anticipates will receive increased use over time. However, the Panel did see some significant limitations in the present version. As a general principle the BBS Web sites need to be more user-friendly than they are currently. In particular, the analysis web site needs to provide for custom definition by users of the set of routes for which to compute a trend; to allow for a defined analysis to be run for multiple species without re-entry of the analysis specification; and to revert following analysis to their immediately antecedent context rather than to the top of the hierarchy of choices.

Recommendation 21: The PWRC Web sites should provide the user with more options for control of Web-based analysis, including user-defined aggregation of routes, looping of analysis over multiple species, and greater conformity to the principle of user control of navigation over the Web site.

Two separate Web sites are maintained by PWRC, one by operations staff, the other by research staff. The Panel considers that users would benefit if the difference in roles of the two sites were better indicated. The Panel suggests that each site display a clear statement of its origin in operations or in research, the particular roles the site is intended to play, and an annotated cross-reference to its opposite number for other roles.

Recommendation 22: Web sites maintained by PWRC in relation to BBS activities should be clearly annotated as to their intended role, with cross-reference to the sister sites for information found uniquely there.

5.2.3.4 Analytical products

Methods of data analysis that are quite different than route-regression have been developed, including non-parametric curve fitting (James et al. 1996) and calculation of annual indices (Mountfort 1985, Collins 1998), both of which address the problem in route-regression of assuming that trends are linear.

While it is important for PWRC and CWS staff to routinely use the method they think most suitable, it is also important for users to have access to alternative/additional products. In particular, results which indicate the non-linearity of population changes are necessary for appropriate interpretation of future prospects for a species (e.g., distinguishing between regular fluctuation vs. long-term consistency), and to generate hypotheses as to causation (such as harsh winters or spruce budworm outbreaks). Annual indices currently presented on the BBS web page are derived from residuals of linear route regression (Sauer et al. 1997), which disguises population fluctuation, particularly when changes are sudden and large (Peterjohn et al. 1995). While the PWRC web site allows calculation of trend data using LOESS smooth methods, there is no option for displaying these results graphically. The Panel would welcome provision on the BBS Web pages of new products that are desired by BBS clients. This could be achieved by greater PWRC or CWS activity or by providing links to the work of other researchers who have produced such products.

Recommendation 23: Explore the viability of simple indices of annual abundance that can be calculated independently of route-regression, even if with less precision, in consultation with experts on alternative methods.

5.2.3.5 Analytical tools

While calling for greater flexibility of user options on the PWRC web site (recommendation #21), the Panel recognizes that not all user needs can be practically addressed at a public web site. Rather than expend PWRC resources on filling orders for custom analyses, a user-friendly analysis program should be available to users for analyzing data on their own, containing as much flexibility and choice of options as possible. Collaboration between PWRC and CWS in meeting this need is highly desirable.

Full development of a portable program for distribution to users to facilitate non-Web use of standard BBS analysis methods is desirable, though not a trivial task. Should this not be feasible, greater attention to improving turnaround to requests for custom analyses is desirable.

Recommendation 24: Complete development of a PWRC/CWS-approved computer program that is flexible, user-friendly and well-documented, for distribution to users wishing to run their own analyses.

The route regression method developed by Patuxent scientists offers a rigorous approach to the analysis of population trends but is nevertheless not universally accepted as the optimal method of analysis. Irrespective of the merits or otherwise of the route regression method, a significant limit to its further development has been the difficulty experienced by outside scientists in reproducing the program used by Patuxent staff so that they can explore

variations in analysis method. Part of the problem is uncertainty over the precise methods used at every stage (since published papers inevitably are unable to provide the level of detail needed for this), but more importantly, a great deal of duplicated effort and expense is going into attempts to re-create an existing program. While PWRC statisticians have shared their code under special circumstances, PWRC staff rely on Gauss programming, which is not commonly used by others, thus necessitating rewriting of code, resulting again in duplicated effort, and adding to the chances of introducing errors. Many statistical procedures published in the technical literature are also made available to users through procedure libraries such as STATLIB [http://lib.stat.cmu.edu/]. Given the great significance attached to the BBS trend analyses produced at PWRC, and in particular the expenditures of significant amounts of public and private funding on the basis of reported BBS decreases, the Panel feels it is important for BBS to be held to the same standard.

Recommendation 25: The standard BBS analysis program should be available to qualified researchers, either as raw code or as library modules compiled from a commonly-used programming language, along with full program documentation.

5.2.3.6 U.S.-Canadian differences

Historically, the CWS used a different approach to BBS analysis than did BRD (Thomas and Martin, 1996), although both agencies use route-regression. Although many of these differences disappeared with the common adoption of estimating equations which obviate the need for log-transformation (Link and Sauer, 1994), there are still several differences of which the Panel is aware. The CWS uses sub-routes as a covariable, instead of observer, since some observers' data are divided into two (or more) "sub-routes" if there are groups of years in which the route was run under very different circumstances - e.g., very different dates - than the others. In most cases sub-route and route are synonymous and the differences present should have no discernible effect on results. However, CWS analysis does not take observer improvement into account, as is done in PWRC analyses (Sauer et al. 1994, 1997). The CWS also uses different weighting factors when aggregating route trends to produce a regional mean. CWS area weighting is for proportion of degree block covered, rather than proportion of physiographic stratum within province, as in the U.S. system. Since Canadian physiographic strata are huge, with some crossing the country coast to coast, and since the BBS in some cases samples only one end, it makes no sense to extrapolate across the whole stratum. Next, the CWS uses a jackknife procedure (sampling without replacement) to estimate variance while the BBS approach uses bootstrapping (sampling with replacement). Also, the CWS uses a t-test as a conservative test of significance of trends because it has smaller samples than the U.S. where z-tests can be used. Finally, PRWC requires a minimum sample size for analysis of 14 routes that have detected a species, while CWS requires 15 routes.

The Panel found some continuing uncertainty in Canada about the details of the aggregation procedures and specific weighting factors used in PWRC analyses, raising some concern about additional, undocumented differences between the two countries' analysis programs. The problem appears to be mainly one of communication. CWS wrote its initial program without detailed knowledge of the contents of the BRD program, and although the BRD provided code for the estimating equation procedure for incorporation into the Canadian program, there has been no detailed comparison of the two programs to identify differences.

Recommendation 26: CWS and PWRC researchers should work together to decide on the best data-selection and weighting methods, and adopt the same analysis method. CWS should only retain differences that are justifiable in the Canadian context, and CWS presentations of Canadian results should clearly state why they may differ from results derived from PWRC analyses for Canada.

Communication and coordination of operations between CWS and BRD appears to be good, and we have no specific recommendations for improvement as to liaison over operations. However, the Review Panel is concerned that there has clearly been a lack of regular communication and cooperation between CWS and BRD statistician/researchers involved with BBS. There has been an unfortunate duplication of effort in developing analysis programs for use by each department and for external use, and historic differences in CWS and BRD analysis methods are largely a result of poor sharing of information. There are no commonly-defined goals for research on BBS or involving its results, and no sharing of work-plans that would preclude further duplication of effort or promote collaborative efforts. Other recommendations in this report may help improve this situation, and implementation of our recommendation for the BBS operations staff to develop in-house capability to run routine analyses may provide a communications link between CWS and BRD. We therefore couch our recommendation here only in general terms, to promote consideration of additional solutions and to emphasize to those involved the importance of regular sharing of information.

Recommendation 27: Encourage greater communication on BBS between statisticians and researchers within BRD and CWS, both to avoid duplication and to promote collaborative efforts on mutually-defined goals for research on BBS and its results, and encourage greater sharing of analysis programs and other information that would promote fulfillment of respective agency goals in each country.

5.2.4 Strategic management issues requiring attention

The Review Panel identified five areas in which PWRC management needs to make strategic decisions. All are issues that will affect the long-term evolution of the BBS Program to greater or less degree.

5.2.4.1. Clarity of operational goals

The Panel was impressed by the focus evident among the BBS staff as to what needed to be done by what date and by the efficiency resulting as to how daily and seasonal tasks were conducted. It was clear to the Panel, however, that resources for performing the volume of work arriving each year are so stretched that some areas of work critical to the long-term success of the BBS Program may not receive adequate attention in the face of more immediate issues.

It was not clear to the Panel that management fully appreciates the tension between the workload in the BBS Office and other duties in the Monitoring Program. The expanding role of the latter into new areas of work could potentially serve as a magnet for the interest and attention of competent and intelligent staff otherwise faced with routine work on the BBS, and the likely impact of such new work on performance of routine BBS duties may be under-estimated by staff anxious to be involved in fresh work. It seemed to the Panel that the ability of the BBS operations staff to produce the routine products of the BBS (e.g., trend analyses) is being

adversely affected by reliance on the willingness of staff to help out on other activities of the Section. Management should be conscious of the extent to which having current staff accepting additional dataset maintenance and analysis responsibilities in the Bird Population Data Center may dilute the effectiveness of BBS operations.

Recommendation 28: Impacts of every proposed new Monitoring Group commitment should be assessed explicitly with respect to the budgetary and staffing needs of the BBS, and any additional workload imposed on BBS staff should be offset with additional resources, as appropriate.

5.2.4.2 Relations between BBS operations and BBS research

Information provided to the Review Panel by BBS operations and research staff revealed an ill-defined interface, and rather different expectations as to the deployment of analytical and programming expertise, between the two groups. The Review Panel was greatly impressed by the creativity and innovation of the Patuxent research staff in devising new ways of using the BBS data and by the associated efforts in outreach with these products. This success in recognizing the needs of the external BBS constituencies and in finding ways to meet them has been outstanding, but at the same time has resulted in the products of this effort becoming the operational norm expected of the BBS. Many users of the research Web site assume this is the outlet for routine BBS products, and turn to the research staff when they want additional products. However, routine products should normally be produced by an operations division rather than by research staff. Currently, user demands for additional products from the research division must either be produced at the expense of other research activities, undertaken during non-work hours, or set aside for lack of time. The appropriate balance between research activity (essentially a constant breaking of new ground) and operations (essentially the reliable provision of standard products) needs greater recognition and involvement by senior management. Some of the problems evident in the BBS program stem from muddling the distinction between 1) an operational program that provides data and certain analyses to any and all users, and 2) a research program that uses BBS data, possibly along with other kinds of information, in various studies.

As noted in other recommendations, the analysis programs for routine products need to be available and useable in the BBS monitoring office to reflect their having become necessary products to users such as USFWS and CWS. As an operational matter, BBS needs to archive the code and products on a yearly basis and to be able to provide the code to other researchers wanting to check uses of the data. This is becoming increasingly critical as more of the analysis products are used for policy and legal documents that researchers need to be able to check, and that ultimately might need to be provided in court. Finally, BBS needs to be sensitive to user needs for additional routine analysis products and should have the capacity to address those needs. These are all appropriate roles for the operations division, and the Panel believes that the monitoring staff must increasingly expect to respond to these demands through allocation of its own resources, rather than relying on the good-will of the research group.

Re-alignment of responsibilities for BBS between research and operations should be undertaken carefully, with the full participation and agreement of involved parties, in order to achieve the desired ends without upsetting the fruitful collaboration that has thus far taken place.

Recommendation 29: PWRC senior management should identify and clarify the respective roles of key individuals within the monitoring and research programs

regarding BBS coordination, data management, data analysis, product development and refinement, user requests, and information transfer.

5.2.4.3 Staffing issues

The Panel concluded that the BBS Program needs some additional staffing to ensure continuing success. Although the Panel heard cases being made for an additional statistician, for a computer programmer, and for a GIS specialist, it is the Panel's considered view that a single professional statistician position is required, to provide programming and statistical support on the operations side. The position should be housed within the operations staff, to provide close ties to the "consumer" of the work products. It is essential that the primary commitment of the position be to the development needs of operations and not to independent research. Among the early duties of such a position should be implementation of our recommendations for new options and information on the Web sites (recommendations 19, 21, 22), implementation of database flags for edits (recommendation #14), user-friendly programs for standardized trend analysis and indices (recommendations 20, 23, 24), and proactive effort in identifying client needs. Where duties overlap with current efforts of research staff, there should be close cooperation among all staff involved (see previous section).

Recommendation 30: Add a full-time operational programmer/statistician whose primary duties would be to supply operational support, to conduct routine analyses, and to produce standard products. This position should be assigned to the Monitoring group.

5.2.4.4 GIS needs and spatial referencing of BBS routes

With the widespread availability of geographic information systems technology, having a database of spatially referenced BBS routes could facilitate additional research and use of BBS data. Fully digitized maps of BBS routes could more easily be joined with digital land-cover information to enable land-cover change detection and description and to facilitate investigation of relationships among patterns of changing land cover and breeding bird population trends at the route level. Such improved research capability, combined with the potential for reduced time on map production activities, at first sight provides attractive reasons for GIS implementation within the BBS Office. However, GIS is notorious in respect of implementation problems when used in production environments, both in terms of equipment and staff expertise, though the situation is improving rapidly.

Over the near-term planning horizon (3 to 5 years), there does not seem to be a need for GIS capability within the BBS Office itself. Digitization of BBS routes would seem best done by contracting with an outside provider, and the primary goal of the digitization would be to facilitate spatially explicit analysis of BBS data e.g., against remotely sensed data. In the future, it is conceivable that digital BBS route maps could be delivered to BBS volunteers or other interested individuals using the Internet and web page technology. Indeed, off-the-shelf software currently exists to allow "cutting" portions of USGS 7.5 minute series topographic maps to user specifications and delivery of the map subset to a personal computer for printing on a color printer. This approach has been adopted for delivery of spatially referenced breeding bird atlas survey block maps to volunteers with Internet access for the Second New York Breeding Bird Atlas Project, scheduled to begin in 2000.

The BBS operational and research staff should define questions they think could be answered with an in-house GIS capability. PWRC should then commission a formal needs assessment to realistically define the costs involved. The Panel suspects that these costs will be too high to support immediate operational use of GIS, but the field is one in which the cost-performance envelope and the need for specialist staff is changing very rapidly, and expert assessment is desirable. Any management decision to proceed to GIS use should be based on perceived cost effectiveness.

In the meantime, the Panel believes that as a short-term goal, PWRC should seek only the digitization of the BBS routes and not the stops along the routes, with advice from the USGS National Mapping Division to assure that digital products meet national map accuracy standards. Spatial referencing of individual stops along a route is desirable for some applications but is likely to be costly if done to the national map accuracy standards required of a Federal agency, and will require involvement of each route surveyor to ensure accuracy of stop location (Dobbyn and Couturier 1998).

Recommendation 31: PWRC should undertake an expert feasibility study of the cost-effectiveness and utility of digitizing individual route stops and of implementing GIS capability within BBS operations. Any perceived need for digitized route locations prior to completion of this assessment should be contracted out rather than conducted in-house.

6. FUTURE DIRECTIONS

Recommendations presented earlier in this report indicate directions that the Panel thinks are important for the future of BBS, such as meeting user needs for new analysis products, making analytical tools more available and improving BBS web sites. On the research side, the Panel has recommended greater investigation of biases inherent in BBS methodology, and continued research into analysis procedures. Here we concentrate on additional directions that will further increase the value of BBS for research, conservation and educational purposes. These directions, involving both BBS Operations and Research, include 1) expanding recognition of the value and uses of BBS data; 2) playing a larger role in integrating BBS results with other monitoring data and providing greater guidance for interpretation; 3) identifying possible causes of population change that should be addressed with other kinds of research; and 4) promoting the use of BBS in new research applications. We discuss these in sequence from more outreach-oriented activities to more scientific activities.

1) Expand recognition of the value and uses of BBS data

BBS publications and web pages have already done an admirable job of making BBS the recognized flagship monitoring program for North American landbirds, but much more could be done to promote the value and uses of BBS. Such a pro-active approach might be met through creating and delivering outreach materials and presentations that are aimed at soliciting new users and uses of the data, e.g. through targeted presentations at professional and ornithological meetings and to other academic and agency groups. Many conservation groups are unaware of the PWRC and CWS web sites with their wealth of useful information, and should be educated as to their existence, encouraged to publish the BBS web site address in their news outlets, and to develop links to the BBS web page from their own web sites. Finally, BBS could make educators more aware of the value of the BBS data and web site as a resource for educational purposes.

2) Play a larger role in integrating BBS results with other monitoring data and providing greater guidance for interpretation

Printed outlets for BBS reports and research results are accessible mainly to the monitoring community and researchers. When BBS results do get wider distribution, such as through BBS web sites or articles written for laymen, they can easily be misinterpreted through lack of context, or from failure by users to understand the limitations and statistical properties of BBS. BBS personnel are the ones most qualified to judge the biological significance of BBS trends, and should do more to ensure that such judgments are as publicly available as the results themselves.

The annual, semi-technical CWS publication 'Bird Trends' attempts to draw together monitoring information from major monitoring programs, present information on the relative quality of data from different sources, and draw conclusions on the probable range-wide population status of species (e.g. Canadian Wildlife Service 1998). Articles are written by the scientists most involved in monitoring , in a style that is accessible to general readers. The Panel lauds the approach and recommends that it be considered in the U.S., along with other means of providing more interpretive context for BBS results (see also recommendation #18).

Recent comparisons of BBS trends to results from other, independently-run population surveys, show considerable agreement in trends (e.g. Hussell et al. 1992, Dunn et al. 1997, Wells et al. 1998). While circumstantial, this is comforting evidence that BBS (and other surveys) are documenting biologically meaningful population change. More work of this type is likely to prove fruitful.

3) Identify possible causes of population change that should be addressed with other kinds of research.

BBS data should be used to a greater extent in identifying possible causation of population change and suggesting specific research questions to verify or refute such hypotheses. For example, some BBS reports have highlighted particular species groups that seem to be declining as groups (e.g. Robbins et al. 1989, Peterjohn and Sauer 1993, Sauer et al. 1996). Other research has linked bird abundance and changes in abundance over time to climatic conditions, both short-term and long-term (Price 1995, Root 1985, 1988). BBS data reflect the effects of spruce budworm outbreaks on bird numbers (Hussell et al. 1992). Much more could be done to use BBS data to suggest specific causes of population change, both using long-term trends and, especially, looking at fluctuation in annual indices (see recommendation #23). While correlation cannot prove causation, BBS results can be used to suggest causation hypotheses that can then be addressed with other kinds of research, and are unique as a resource for addressing regional and continental phenomena.

4) Promote the use of BBS in new research applications

Given the original goals of the BBS as a population monitoring program, it is hardly surprising that the vast majority of papers using BBS data have addressed the analysis of trends and the presentation of results. Here the Panel wishes to welcome and encourage the recent broadening of research interests in BBS.

For example, several recent publications have brought a geospatial perspective to analysis of the BBS data. These include analyses of autocorrelation in species distribution (Maurer 1994) and analyses of the extent to which dynamics at individual BBS routes are correlated across space (Koenig 1999). These publications are pioneering examples of the kind of spatially explicit analyses now possible with the BBS data. No other dataset offers the comprehensive coverage of continental distributions, thus making the BBS a unique resource in addressing spatial issues impinging on environmental and conservation science. This type of work would be facilitated if PWRC were to develop a dataset of georeferenced BBS route information (see recommendation #31). However, spatial analysis of BBS data also requires a better understanding than currently prevails of the extent to which spatial representativeness and autocorrelation hold for individual years and for data aggregated across years. Such issues can be addressed by external analysts, but PWRC staff have detailed familiarity with the BBS dataset that is likely to bring valuable insight to such research, and provide reassurance as to the suitability of the BBS for spatial analyses.

Recommendation 32: PWRC and CWS should be proactive in expanding recognition of the value and uses of BBS data, playing a larger role in integrating BBS results with other data and research.

7. PRIORITIES AMONG RECOMMENDATIONS

A difficulty experienced by the Panel in trying to decide on the relative priority of its different recommendations was the need to advance on several fronts: multiple recommendations on some facets of the BBS appear as important as a single recommendation on other topics. The Panel therefore decided to organize its recommendations by general area of activity, so that some sense of the relative importance of the recommendations offered within that general area could be offered, while at the same time the need for parallel attention to urgent issues in other areas could be indicated. A high priority ranking reflects the Panel's belief that the BBS program is either compromised by or is seriously limited by failure to address these items. Such recommendations address critical issues not currently being addressed that deserve BBS management attention in the near future. Recommendations of medium priority are considered of lower importance for immediate BBS management action but are considered to be of strategic importance for the long-term health of the BBS. Low priority recommendations are in essence calls for greater use of best scientific practice in areas of lower strategic importance to the BBS. The Panel suggests a two-year time-line for results on high priority recommendations, and a maximum of five years for medium priority recommendations.

7.1. Programmatic support

High Priority

Recommendation 29: PWRC senior management should identify and clarify the respective roles of key individuals within the monitoring and research programs regarding BBS coordination, data management, data analysis, product development and refinement, user requests, and information transfer.

Recommendation 30: Add a full-time operational programmer/statistician whose primary duties would be to supply operational support, to conduct routine analyses, and to produce relatively standard products. This position should be assigned to the Monitoring Group.

Moderate Priority

Recommendation 28: Impacts of every proposed new Monitoring Group commitment should be assessed explicitly with respect to the budgetary and staffing needs of the BBS, and any additional workload imposed on BBS staff should be offset with additional resources, as appropriate.

7.2. Scientific quality

High Priority

Recommendation 4: Assess the extent to which the habitats sampled by BBS routes are representative of the geographic areas for which trends are reported, at regular and frequent intervals, preferably every five to ten years.

Recommendation 5: Give greater attention to the potential biases introduced into the BBS dataset by the loss of routes as a consequence of traffic growth. Conduct an analysis of the possible effects of route replacement on trend estimates and develop a Standard Operating Procedure as to the most appropriate treatment of data involving route replacement.

Recommendation 6: Conduct a technical evaluation of the empirical effects of spatial and temporal variation in detection probability. Initial work should examine the feasibility of the alternative approaches to the problem, followed by implementation of the selected option.

Moderate Priority

Recommendation 1: The magnitude and direction of the potential on-road bias associated with the roadside nature of the BBS counts should be expressly investigated by testing for attraction or repellent effects of roads with paired counts on and off roads within the same habitat, replicated in different habitats and regions. Alternatively, putative bias could be addressed by building off-road sampling into the BBS protocol.

Low Priority

Recommendation 2: Investigate the feasibility of conducting a designed study to systematically investigate the extent, if any, to which species trends differ on and off roads.

7.3. Trend analysis

High Priority

Recommendation 25: The standard BBS analysis program should be available to qualified researchers, either as raw code or as library modules compiled from a commonly-used programming language, along with full program documentation.

Recommendation 26: CWS and PWRC researchers should work together to decide on the best data-selection and weighting methods, and adopt the same analysis method. CWS should only retain differences that are justifiable in the Canadian context, and CWS presentations of Canadian results should clearly state why they may differ from results for Canada derived from PWRC analyses.

Moderate Priority

Recommendation 8: Continue effort to determine the strengths and weaknesses of alternative methods of trend analysis and the circumstances under which each is appropriately used.

Recommendation 23: Explore the viability of simple indices of annual abundance that can be calculated independently of route-regression, even if with less precision, in consultation with experts on alternative methods.

Recommendation 24: Complete development of a PWRC/CWS-approved computer program that is flexible, user-friendly and well-documented, for distribution to users wishing to run their own analyses.

Low Priority

Recommendation 20: On all BBS Web pages that present bootstrap analyses, provide an option for seeding the random number generation to ensure exact replication of bootstrap sequences.

7.4. Operational management

High Priority

Recommendation 3: Establish a working group to develop operational methods of obtaining periodic habitat and other environmental information along BBS routes (ideally every five to ten years).

Recommendation 14: Develop a Standard Operating Procedure to enforce consistency in editing and to ensure that all edits to the database are reversible and clearly documented. These standards should be applied retrospectively, documenting where they cannot be met.

Recommendation 17: Make timely release of each year's BBS data a high priority.

Recommendation 19: Develop a Standard Operating Procedure to ensure documentation of changes to BBS Web sites, at the minimum issuing a new version number for a modified program or dataset and documenting the explanation of the changes. Such version numbers should be cited in all publicly available analyses.

Moderate Priority

Recommendation 7: The BBS should continue to study the magnitude of observer variability, its effects on BBS results, and methods of addressing observer effects during data analysis.

Recommendation 9: Greater effort should be devoted to achieving appropriate geographic coverage by the BBS, specifically by filling major gaps in coverage within the existing BBS coverage area in the U.S. and Canada, and by continuing efforts to extend BBS into Mexico.

Recommendation 12: Begin discussions with State Coordinators and BBS participants to identify ways to increase and strengthen observer participation in the BBS in preparation for its anticipated growth in scale and intensity.

Recommendation 13: Develop programs to train observers to consistent high standards, particularly to reduce variation in detection probability between observers.

Recommendation 15: Assess the utility or otherwise of non-standard routes and define appropriate Standard Operating Procedures for the treatment of recommended types.

Recommendation 18: Publish, either via the Web or in the literature, an assessment for every species represented in the BBS database, indicating geographic, temporal, and other major limitations in sampling that affect quality or generality of trend estimates. All PWRC web sites presenting BBS results should indicate which species have had such limitations identified (preferably linking to the specific details).

Low Priority

Recommendation 16: Discontinue the practice of processing the historical files to yield stop-level digital data but allow access to the clerical records (with appropriate precaution against loss of the originals) upon request, with the expectation that the individual researchers involved will meet the costs of processing such data for specific research projects. The possibility of PWRC receiving an archival copy of any new or revised digital data should be discussed with the Principal Investigator and the funding agency at the time of the request for access to the original.

Recommendation 31: PWRC should undertake an expert feasibility study of the cost-effectiveness and utility of digitizing individual route stops and of implementing GIS capability within BBS operations. Any perceived need for digitized route locations prior to completion of this assessment should be contracted out rather than conducted in-house.

7.5. Communications and information transfer

High Priority

Recommendation 27: Encourage greater communication on BBS between statisticians and researchers within BRD and CWS, both to avoid duplication and to promote collaborative efforts, and there should be greater sharing of analysis programs and other information that would promote fulfillment of respective agency goals in each country.

Moderate Priority

Recommendation 11: Promote greater outreach to BBS stakeholders, especially BBS State Coordinators. Major elements in this outreach should include increased personal contact between staff and volunteers, and the conduct by BBS staff of workshops and other activities strengthening a sense of participation by stakeholders in the BBS.

Recommendation 21: The PWRC Web sites should provide the user with more options for control of Web-based analysis, including user-defined aggregation, looping of analysis over multiple species, and greater conformity to the principle of user control of navigation over the Web site.

Recommendation 32: PWRC and CWS should be proactive in expanding recognition of the value and uses of BBS data, playing a larger role in integrating BBS results with other data and research.

Low Priority

Recommendation 10: PWRC and CWS researchers should periodically and formally review the technical research needs of the BBS program, taking costs and benefits into account, and make recommendations to

BBS management as to priorities for ensuring that needed research will be carried out.

Recommendation 22: Web sites maintained by PWRC in relation to BBS activities should be clearly annotated as to their intended role, with cross-reference to the sister sites for information found uniquely there.

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